AD-A097 719 SMITHSONIAN ASTROPHYSICAL OBSERVATORY CAMBRIDGE MASS F/G 8/10
PERFORM A GRAVITY CORRELATION STUDY.(U)
OCT 80 M C ROUFOSSE F19628-80-C-0006
UNCLASSIFIED AFGL-TR-80-0268 NL

1 OF 1
AD A
097719

END
DATE
FILMED
5-81
DTIC

(12)

AFGL-TR-80-0268

LEVEL II

PERFORM A GRAVITY CORRELATION STUDY

Micheline C. Roufosse

Smithsonian Institution
Astrophysical Observatory
60 Garden Street
Cambridge, Massachusetts 02138

Final Report
1 October 1979 - 30 September 1980

August 1980

Approved for public release, distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

Qualified requestors may obtain additional copies from the Defense Technical Information Center. All others should apply to the National Technical Information Service.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFGL-TR-80-0268	2. GOVT ACCESSION NO. AD-A097	3. RECIPIENT'S CATALOG NUMBER 729
4. TITLE (and Subtitle) Perform A Gravity Correlation Study.		5. TYPE OF REPORT & PERIOD COVERED Final Report 1 Oct [redacted]79 — 30 Sep[redacted]80
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Micheline C. Roufosse		8. CONTRACT OR GRANT NUMBER(s) F19628-80-C-0006
9. PERFORMING ORGANIZATION NAME AND ADDRESS Smithsonian Astrophysical Observatory 60 Garden Street Cambridge, Massachusetts 02138		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102F 2309G1AY
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Monitor/Thomas P. Rooney/LWG		12. REPORT DATE Oct[redacted]1980
		13. NUMBER OF PAGES 19
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Geoid Heights	Seamounts
Altimeter	Thin elastic plate model
Flexure of the lithosphere	Time evolution

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The aim of this work is to study the mechanical properties and time evolution of the lithosphere. For that purpose, geoid heights derived from the Geos 3 and Seasat radar altimeters were used. The study of the correlation existing between bathymetry and free-air anomalies or geoid heights gives information on the mechanical properties of the lithosphere and its thickness. The lithospheric thickness is related to the age of the lithospheric plate, and by probing several locations spanning varied temporal

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified 044850

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Cont.)

situations, we are able to retrace the time evolution of the lithospheric plates. Toward that aim, several seamount chains, islands, and ridges have been investigated in the Pacific, Atlantic, and Indian Oceans.

In the regions studied so far, the age of the lithosphere at the time of loading is the primary parameter. In this work, we attempt a systematic study of all the parameters influencing the observed mechanical properties of the lithosphere.

The object of this research is to study the time evolution of the mechanical properties of the lithosphere using radar altimeter data. This is done by studying the correlation existing between the short wavelength features in the geoid heights and bathymetry.

In this work, we have restricted ourselves to the study of linear bathymetric features; seamount chains. For such features, it is quite legitimate to consider individual satellite passes crossing the chain of seamounts at an angle as close as possible to 90° and it is thus unnecessary to go through the tedious procedure of adjusting all satellite passes into a coherent network by calculating and removing a bias and trend. Dealing with individual satellite passes is furthermore ideal to study the evolution along a seamount chain.

Following Crough (1975), we can consider the lithosphere as a thin plate whose thickness increases with increasing time up to a certain age, of the order of 80 m.y., and then continues to increase at a progressively lower rate until it reaches equilibrium thickness. Since the thickness of a plate influences its mechanical properties, it is possible to study the time evolution of the lithosphere by observing how it deforms when loaded by seamounts placed at several points along its evolutionary path. To examine the mechanical properties of the lithosphere, we assumed the thin-plate model developed by McKenzie and Bowin (1976) and explained in Roufosse (1980). In this model, the lithosphere consists of a thin elastic plate overlying a fluid medium; the plate is being loaded by bathymetric features such as seamounts, island chains, and ridges and is subsequently deformed. The magnitude and wavelength of the deformed area depend mostly on the flexural rigidity, which is proportional to the cube of the lithospheric thickness. By studying the correlation function between the geoid height and the bathymetry, we can determine the flexural rigidity of the area under investigation. For that purpose, we calculate a theoretical filter $Z(k)$ in wavenumber space by using the thin-plate model (McKenzie and Bowin, 1976) and varying the values for the flexural rigidity:

$$Z(k) = \frac{3(\rho_c - \rho_w)}{2r\rho_e} \frac{(1 - e^{-wkt}) e^{-wkd}}{[1 + (wk)^4] wk} \tag{1}$$

where

$$\gamma = \left[\frac{(\rho_m - \rho_c) g}{F}\right]^{1/4} , \tag{2}$$

$$w = \frac{2\pi}{n\Delta\gamma} .$$

In these expressions, ρ_c, ρ_w, ρ_m, and ρ_e, are, respectively, the crustal, water, mantle, and mean-earth densities, r is the earth's equatorial radius, t is the crustal thickness, d is the water depth, g is the average gravity, F is the flexural rigidity, n is the number of points in the filter, and Δ is the spacing between consecutive points of the filter. The filter derived in equation (1) is then Fourier-transformed into direct space and convolved with the bathymetry, resulting in a theoretical geoid height. The value for the flexural rigidity that gives the best agreement between predicted and observed geoid heights is the one that will be selected for each area studied. In that framework, we have studied several chains of islands in the Pacific. According to Morgan (1972), the main chains of islands in the Pacific are the consequence of the Pacific plate moving over three fixed hot spots located respectively.

1) At Hawaii, responsible for the Hawaiian Emperor Seamount chain.

2) At McDonald, responsible for the Austral, Tubuai, Marshall-Gilbert seamount chains.

3) At the intersection of the East Pacific Rise and the Tuamotu and Sala y Gomez ridges, responsible for the Tuamotu-Line seamount chains. This can be seen in Figure 1. The age of these seamounts thus increases towards the north-west.

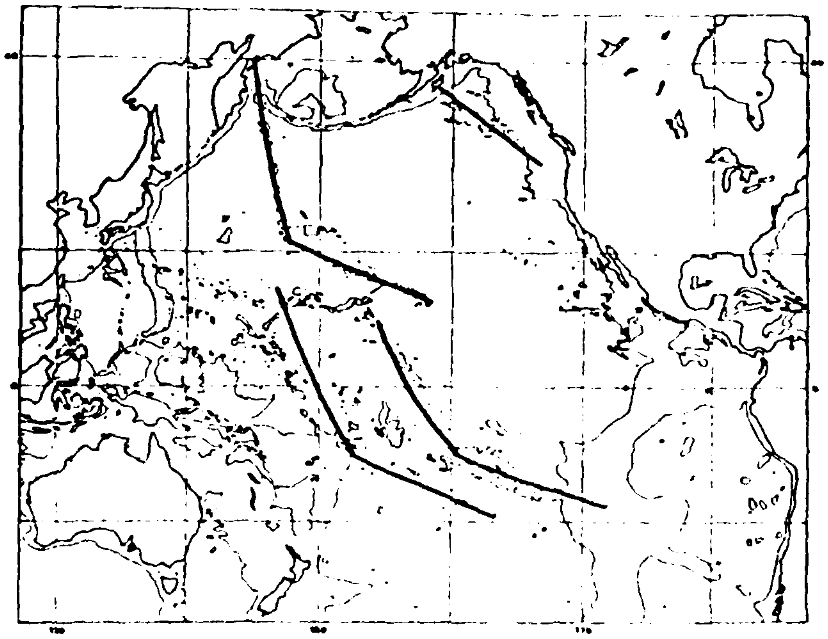

Figure 1. Hot spot trajectories in the Pacific plate.

The Hawaiian-Emperor Seamount chains have been studied first and the results have been reported in Scientific Reports 1 and 2. The values for the flexural rigidity range between 1 and 3×10^{30} dyne-cm for the Hawaiian chain and between 5 and 8×10^{29} dyne-cm for the Emperor chain. These results are in agreement with those reported by Watts (1978) using surface ship gravity data.

The next features studied are the chains of seamounts produced by the hot spot located at the intersection of the East Pacific Rise and the Tuamotu and Sala y Gomez ridges; the Tuamotu-Line chains. The Tuamotu Islands constitutes the youngest section of this alignment; their ages range between 37 and 40 M.Y. while the Line island ages range between 40 and 97 M.Y. The lithosphere underlying the Line Seamounts is of the order of 80 to 100 M.Y. whereas that underlying Tuamotu Seamount is younger, of the order of 70 M.Y. The lithosphere was thus older when it was loaded by the Tuamotu Seamounts than by the Line islands. The values for the flexural rigidity that best predicts the behavior of the geoid for the Line islands is of the order of 1.0 to 2.5×10^{29} dyne-cm while it ranges between 2.5 and 5.0×10^{29} dyne-cm in the case of the Tuamotu islands. Figures 2 and 3 show the observed and predicted geoid heights in the case of the Line islands. Figure 4 represents the observed and predicted geoid heights and the bathymetry of the Tuamotu islands.

Finally, we have studied the two chains of seamounts produced by the McDonald hot spot. The Tubuai Austral Cook Seamounts are quite young; their age range between 5 and 25 M.Y. The Marshall-Gilbert Seamounts constitute the oldest section with ages varying between 40 and 70 M.Y. The values for the flexural rigidity associated with the youngest seamounts vary between 7.5×10^{29} and 10^{30} dyne-cm while that associated with Marshall-Gilbert range between 2.5 and 5×10^{29} dyne-cm. Figure 5 represents the geoid signals associated with two seamounts of different ages but similar size and loading lithosphere roughly the same age. The left smaller signal is associated with the older seamount (Tuamotu chain) while the right more intense signal is

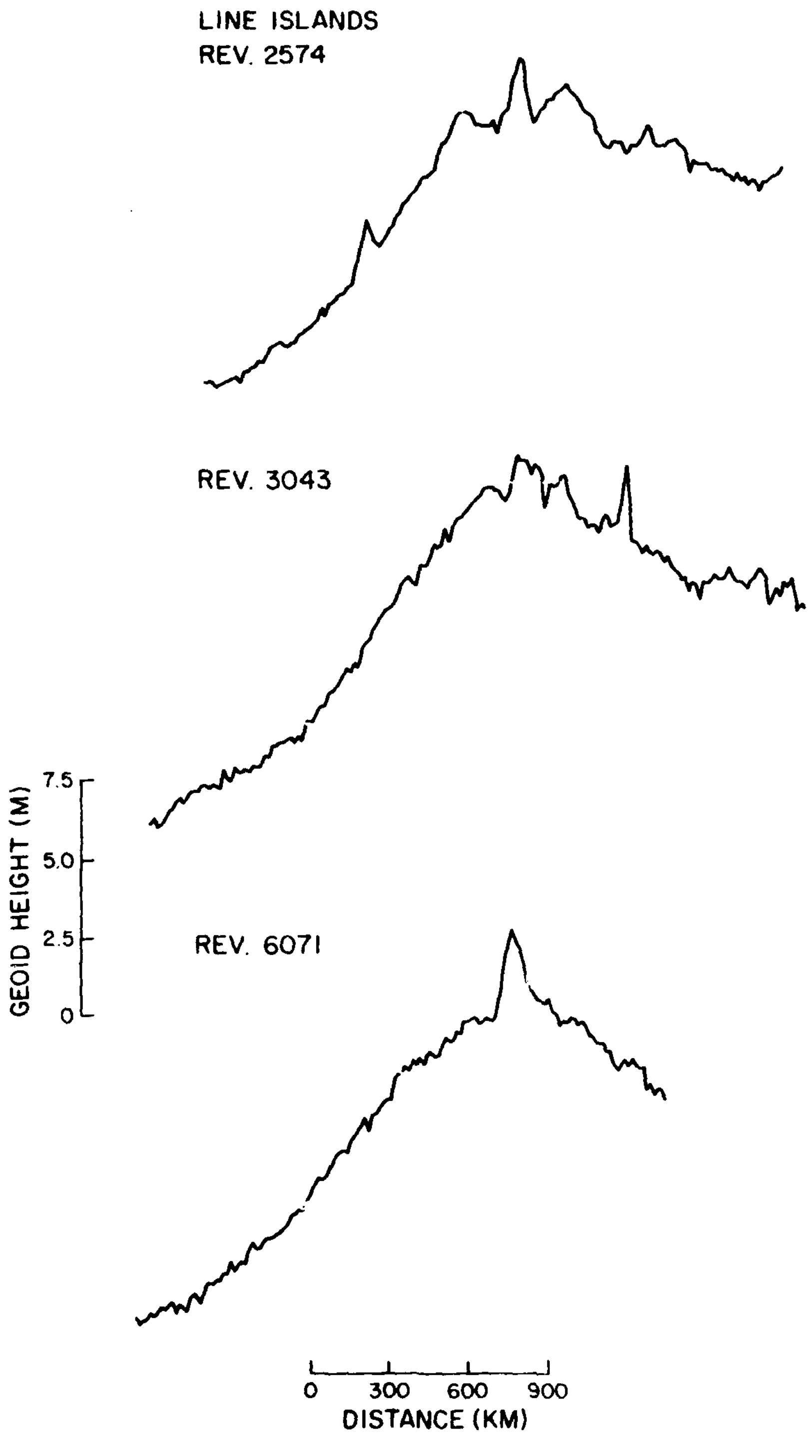

Figure 2. Three geoid height profiles crossing the Line Seamount chain. They are represented with respect to a reference geoid of degree and order calculated with GEM 10.

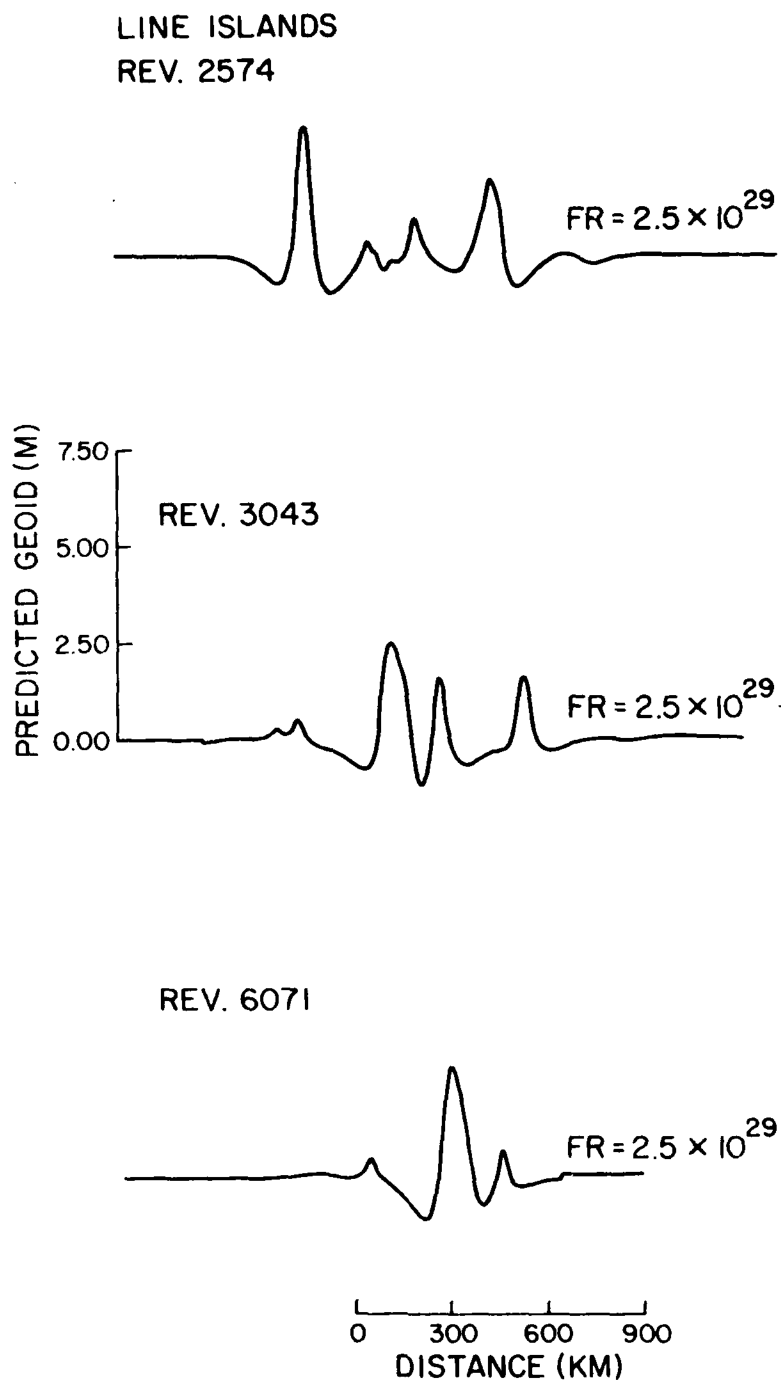

Figure 3. Three predicted geoid height profiles crossing respectively the Line Seamounts chain at the same locations as the observed geoid height profiles shown on Figure 2.

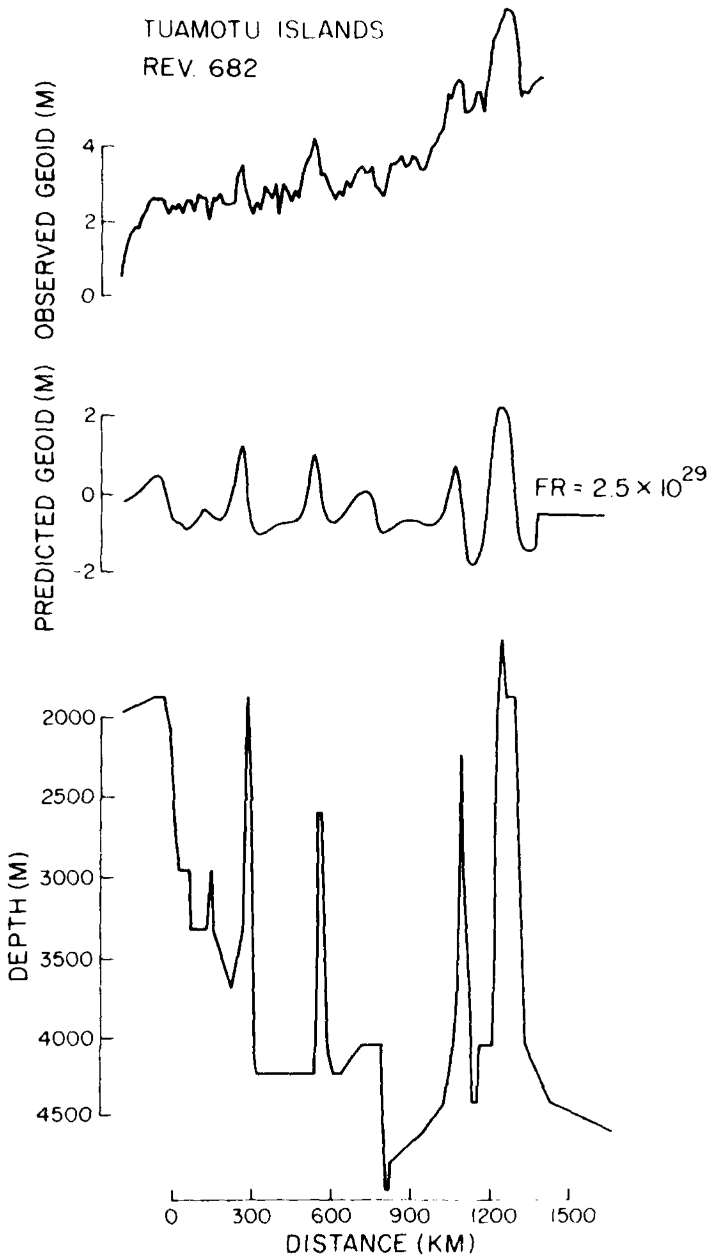

Figure 4. The top profile represents the observed geoid height with respect to a reference geoid of degree and order 16 calculated with GEM 10 across the Tuamotu Seamounts chain. The intermediate profile represents the predicted geoid height profile calculated with a value for the flexural rigidity of 2.5×10^{29} dyne-cm. The bottom profile represents the bathymetry reconstructed from contour charts along the subsatellite positions.

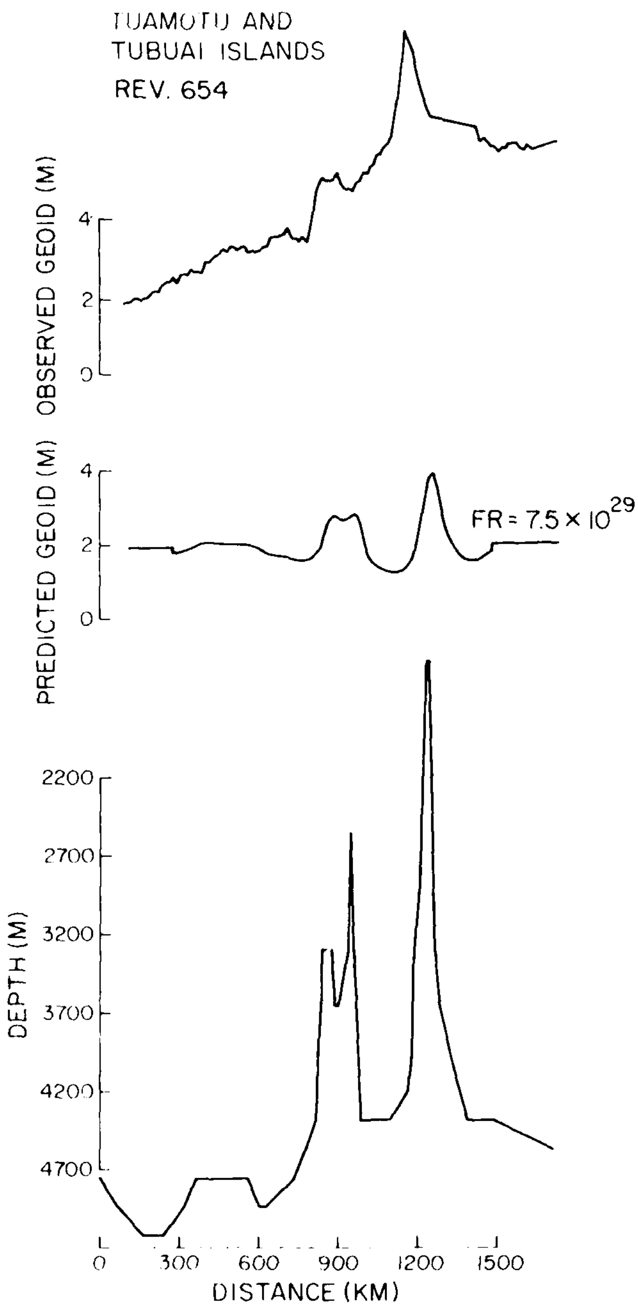

Figure 5. Same as Figure 4 for a profile crossing the Marshall Seamounts chain.

associated with the younger seamount (Tubuai chain). It is quite clear that they cannot be explained and reproduced from bathymetry with the same correlation function. The younger seamount requires a larger value for the flexural rigidity 7.5×10^{29} dyne-cm versus 2.5×10^{29} dyne-cm for the older seamount. The parameter which mostly influences the geoid signal is thus the age of the lithosphere at the time of loading. Quantitatively, the agreement is quite reasonable, taking into account the large uncertainties in the prediction of the ages of the seamounts. From the values for the flexural rigidity, the lithosphere was roughly twice as old when it was loaded by Tubuai and Tuamotu, in good agreement with available age data.

We have also studied the New England seamounts. Two typical passes can be seen on the top profiles of Figures 6 and 7. The signals observed have a wavelength of 150 to 200 km and an intensity of 2 to 3 m. It is quite similar to the signal observed in the Marshall-Gilbert seamount area.

The results can be seen on the bottom profiles of Figures 6 and 7. These profiles represent the predicted geoid calculated using a value for the flexural rigidity ranging between 1.5 and 3×10^{29} dyne-cm. We have not yet found accurate information on the age of the seamounts in that area, but the lithosphere is quite old, of the order of 159 m.y ; we can thus deduce that the New England seamounts are quite old and were formed when the lithosphere was young and thin.

We have also studied the Rio Grande Rise in the South Atlantic Ocean. This area was chosen in order to be compared with the Walvis Ridge area studied previously and is located symmetrically with respect to the Mid-Atlantic Ridge. The Walvis Ridge was studied last year and the results have been reported in Roufosse (1979). The Ridge is made up of three main segments:

- The eastern and central segments which were formed simultaneously with the lithosphere by a hot spot located on the mid-Atlantic Ridge.

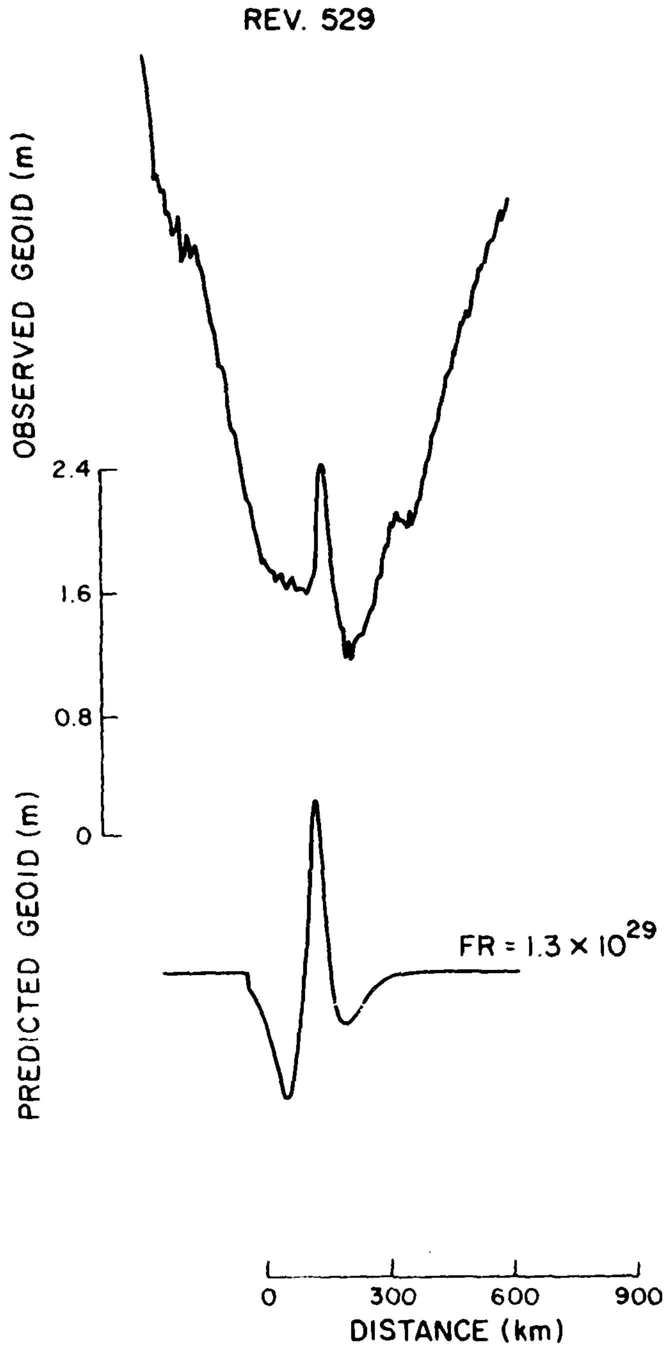

Figure 6. The top profile represents the observed geoid heights for the Seasat revolution number 529 over the New England seamounts. The bottom profile represents the predicted geoid heights calculated with a value for the flexural rigidity of 1.3 × 10^{29} dyne-cm.

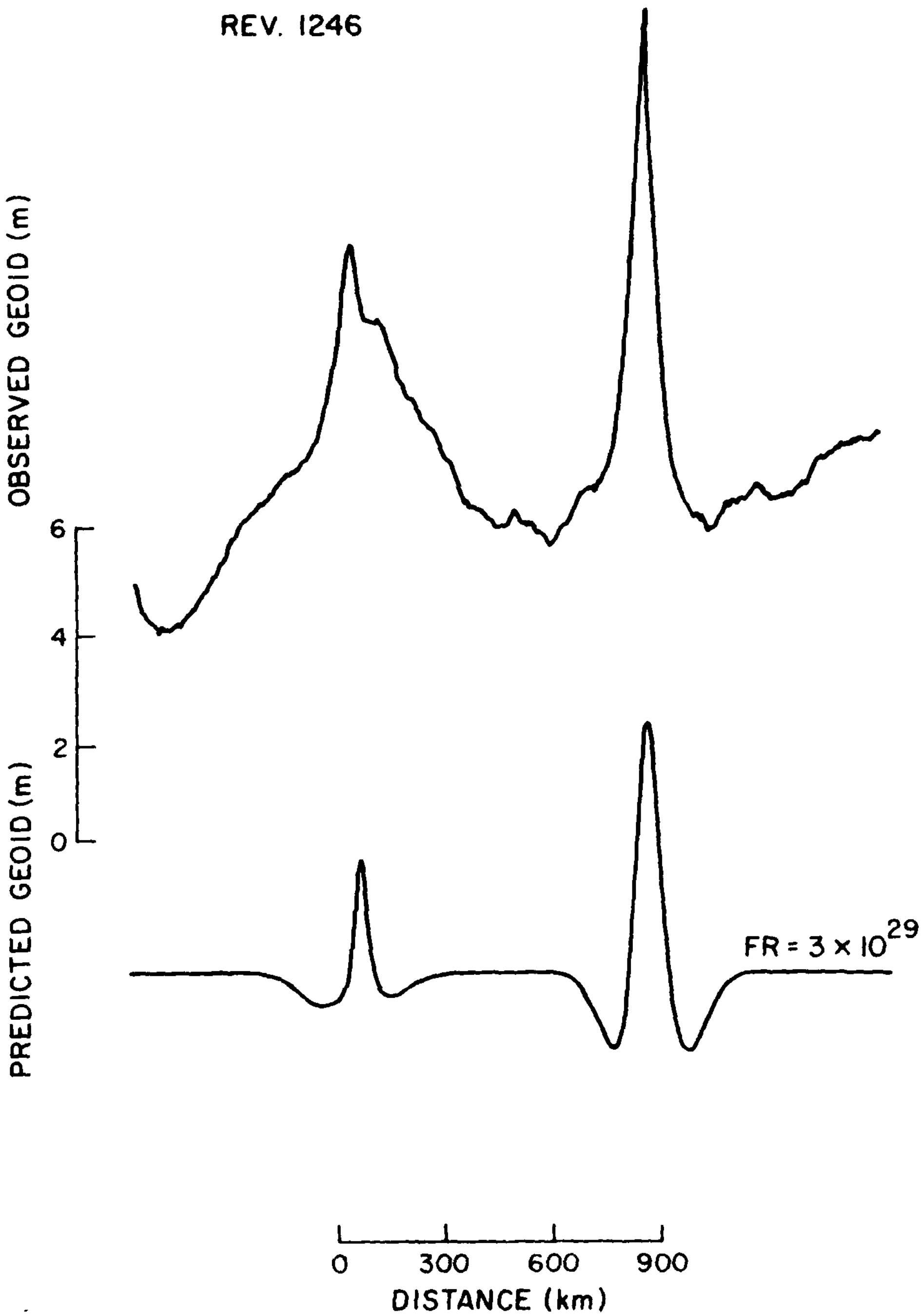

Figure 7. The top profile represents the observed residual geoid heights for the Seasat revolution number 1246 over the New England seamounts. The bottom profile represents the predicted geoid heights calculated with a value for the flexural rigidity of 3×10^{29} dyne-cm.

The western section which was formed on young lithosphere by a hot spot located in the vicinity of Tristan Da Cunha and Crough islands.

It was found that an Airy model with crustal thickening of about 25 km best described the eastern and central sections whereas a thin elastic plate model with values of the flexural rigidity of the order of 2 to 5 × 10^{29} dyne-cm best accounted for the western section. These results are in agreement with gravity and seismic data interpreted by Goslin, Mascle, Sibuet, and Hoskins (1974); Goslin and Sibuet (1975); Dingle and Simpson (1976); Detrick and Watts (1979).

The geoid signals present in the Rio Grande Rise region are weak and broad and mostly resemble those observed in the eastern and central sections of the Walvis Ridge. At this point of the study, we believe that the Rio Grande Rise has been formed simultaneously with the eastern and central sections of the Walvis Ridge by a hot spot located on the Mid-Atlantic Ridge. An Airy type model of compensation can best describe the signal observed. Since little Seasat data was available in the Southern Hemisphere, we had to use Geos 3 data to provide the necessary data coverage for this study.

REFERENCES

Crough, S. T., 1975. Thermal model of oceanic lithosphere. Nature, vol. 256, pp. 388-390.

Detrick, R. S., and Watts, A. B., 1979. An analysis of isostasy in the world's oceans: Part 3 Aseismic ridges. Journ. Geophys. Res., in press.

Dingle, R. V., and Simpson, E. S. W., 1976. The Walvis Ridge: A review. In Geodynamics: Progress and Prospects, ed. by C. L. Drake, American Geophysical Union, Washington, D.C., pp. 160-176.

Goslin, J., Mascle, J., Sibuet, J. C., and Hoskins, H., 1974. Geophysical study of the easternmost Walvis Ridge, South Atlantic: Morphology and shallow structure. Geol. Soc. Amer. Bull., vol. 85, pp. 619-632.

Goslin, J., and Sibuet, J. C., 1975. Geophysical study of the easternmost Walvis Ridge, South Atlantic: Deep structure. Geol. Soc. Amer. Bull., vol. 86, pp. 1713-1724.

McKenzie, D. P., and Bowin, C., 1976. The relationship between bathymetry and gravity in the Atlantic Ocean. Journ. Geophys. Res., vol. 81, pp. 1903-1915.

Morgan, W. J., 1972b. Plate motions and deep mantle convection. Geol. Soc. Amer. Mem., vol. 132, pp. 7-22.

Roufosse, M. C., 1979. Study of oceanic lithosphere using GEOS-3 radar altimeter data. Final Report, AFGL-TR-79-0181.

Roufosse, M. C., 1980. Study of the time evolution of the lithosphere using GEOS-3 radar altimeter data. In preparation.

Watts, A. B., 1978. An analysis of isostasy in the world's oceans: 1, Hawaiian-Emperor Seamount chain. Journ. Geophys. Res., vol. 83, pp. 5989-6004.

END

DATE
FILMED

5-81

DTIC